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DETERMINATION OF THE LUMINOSITY OF AIR, N_2 AND CO_2 AT TEMPERATURES OF $\sim 10,000^{\circ}K$

by

N. N. Ogurtsova, N. V. Podmoshemsky
V. M. Shelemina

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In experimental determination of the luminous capability of gases in high-temperature areas, the greatest difficulties are created in the appropriation of corresponding sources of plasma. In Chapter [1] a special arc with plasma extraction from the area of the electrodes was proposed and developed, which allowed clear gaseous plasma, free from electrode contamination, in the interval of temperatures from 6,000-30,000° K to be developed. However, the column of such an arc is not homogenous in a temperature aspect which makes it impossible to determine the conditions of optical measurements, in which luminosity is always measured, corresponding to combinations of zones which are different in temperature, lying in the projected direction. Creation of a radially dispersed temperature through an Abel integral, closely connected with the significant error. Along with this, in the instance of determining the integral along the spectrum of luminosity, when it is necessary to conduct thermoelectric measurements along the points, consecutive in time, the accuracy of measurement appears to be extremely low. If consideration is made for an especially high dependence of the energy luminosity of gases, on temperature (approximately T^{15}), then it becomes obvious, that such an arc is of little use as a source for quantitative measurements of luminosity energy.

In this plan, the best method of abstaining from difficulties is the formation of an arc source with homogenous plasma, minus the above-indicated deficiencies.

Homogenous arc source for the investigation of gas luminosity. At the present time, within the area of spectrographic investigations, wide use was established for long arcs, stabilized by cooling walls, by whirl currents of gas or liquid, for which high temperature plasma homogeneity is achieved to facilitate observation within limits of a small solid angle, in an axial direction. However, in this case under great voltages the homogeneity of plasma composition is destroyed, since during observation along the axis to the unknown luminens of the central zone, controlling luminence is added which greatly differs in the plasma composition of the electrode areas.

Electrode contamination may be removed from long-stabilized arcs, by sucking plasma through electrodes [1] and in this way preventing the contaminating substance of the electrodes from appearing in the canal.

Drawing 1 shows the principle schematic of the homogenous arc source for luminating capabilities of gases under high temperatures. For stabilization of the arc, we used five copper diaphragms with thicknesses of 3 mm, with 1.5 mm. spaces between them. The arc was stabilized by whirl currents of the gas being studied, which was tangentially blown in through six canals, made in each diaphragm. The gas flowed through the spaces between the diaphragms and the central openings of the diaphragms. A great enough quantity of diaphragms, and also the possibility of radially flow of the actual portion of the working gas allowed, in comparison with devices of the plasmatronic type, for a temperature increase in the homogeneity along the axis of the canal stabilized by the blow.

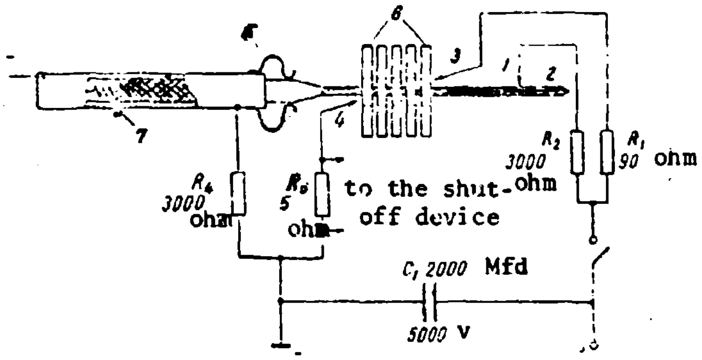

Figure 1. The Principle Schematic of the Homogenous Arc Source

1, 2--electrodes of the auxiliary arc; 3, 4--basic discharge electrodes; 5--current carrying con.cnts of the auxiliary arc; 6--copper diaphragms; 7--Kirkhoff's fall.

Arc feeding is accomplished by batteries from condensors IM-5-150 with a capacity of 2,000 mfd, loaded to a voltage of 5,000 v. Utilization of impulse feeding significantly aided the heat regime of the device, which allowed it to work under these conditions at the heat inertia of the limiting flaps without special water cooling.

The condenser battery was placed in the arc electrode circuit through resistances of approximately 50-100 ohms. The constant drop in the arc current was 0.1-0.2 seconds. During photographic investigation, with the help of photo shutters, exposition on an order smaller than the constant discharge of the battery was established, so that deviation from the average current discharge during the time of exposition did not go over 10%. Shutter fali was accomplished with the help of an electromagnet, the windings of which were being supplied by voltage from resistor R_5, including in the chain of the arc under investigation. This process automatically synchronized the opening of the shutter with discharge. The delay began the exposition relative to the beginning of discharge, was determined by the release time of the shutter and electromagnet. Oscillographic measurement showed, that in the given case the delayed time was equal to 0.03 seconds at reproduction ±15%. The exposition time was 0.02 seconds at reproduction ±5%.

Ignition of the basic arc is accomplished by a method of drawing the arc through an interval in the auxiliary arc by current force of 1 a, burning between the immovable (1) and mobile (2) electrodes.

Photographs of the arc showed, that depending on the regime, the diameter of the column of discharge equals 2-3 mm, and the homogeneity in temperature preaxial zone, for which we conducted measurements of energy luminens, comprises 1.5-2 mm. Observation along the anergic axis of such a source shows a corresponding equality of 1/20. Under these conditions, in order to have a determined fixed length for the luminating layer of plasma, it is necessary to accomplish a sufficient correspondence of the canal axis with the optical axis of the registering system.

It was experimentally shown, that the position of the arc column in the canal, formed by the diaphragms, is determined by the velocity of the tangential blow on the arc and magnetic forces of the current, the action of which must be especially strong by the exit from the diaphragms, where the plasma cord turns to the electrode. The timely arc turns shown on the spectrochronograph with EOP [2] showed, that as a rule, an increase in the blow destroys the spacial durability of the arc and is followed by emanations of plasmic torches through the vertical openings. Along with this, the presence of a large discharge current, the stable position of the canal is realized in the presence of a significantly lower blow, which is

GRAPHICS
NOT REPRODUCIBLE

one of the basic reasons for the poor dependence of plasma temperature on the current discharge, observed during the experiment. The authors conducted measurements of the luminous capabilities of gases under conditions of current discharge at 50 and 100 a. As is seen from the table, when the current is increased by two times the temperature of the plasma, increases to only 3%. Along with this, it was necessary to decrease the tangential blow within the same proportions.

Figure 2. Photograph of the Arc Canal. Top view.

It is necessary to remark, that in the case of discharge into CO_2, the stability of the canal position is significantly worse than upon discharge into air or nitrogen: so, at current strength of 100 a, the arc in CO_2 did not have a chance to collect enough stable conditions, necessary for the conduction of measurements. Determination of the luminous ability of CO_2 was carried out at current strength of 50 a.

For working regimes using a method of varying the velocity of whirl currents stabilizing the gas arc, conditions of greater durability were chosen. When the axis of the arc column corresponds with the canal axis, formed by the diaphragm , this significantly aided the enclosure of the arc. The length of the plasma column being investigated is determined by the photographs of the arc, drawing 2, and equals 23 mm. The error in determining the length of the lumination layer in the case of discharge in air and N_2 did not exceed 20%, for CO_2--50%. In comparison with the earlier proposed source [1], under these conditions the length of the homogenous column in practical constant determinations of the nonhomogenous zone increased approximately on the same order, resulting in the betterment of temperature homogeneity of the plasma under investigation on the same order.

Drawing 3 shows, (see paste in to page 781) spectrum photographs of the homogenous arc source, produced by the quartz spectrograph ISP-22. From the drawing it can be seen, that in such a discharge, the gas spectrum is excited, creating whirl stabilization of the canal. The substance of the diaphragm (Cu), isolating the lateral surface of the electrode caps (Si) and electrodes (C), are practically lacking in the plasma canal, which is indicated by a lack of traces of resonant lines of these elements in the discharge spectrum.

By this method, the proposed arc source contains a sufficiently high homogeneity of plasma, allows for the provision of clean conditions for excitation of gases and, also, is useful for quantitative measurement of

Plasma Characteristics	Air ($T = 9000 \pm$ [illegible] K, T_{H} = [illegible] K)	N_2 ($T = 9000 \pm 200^\circ$ K)	CO_2 ($T =$ [illegible] $\pm 200^\circ$ K)	Air ($T = 10\,300 \pm 150^\circ$ K)	N_2 ($T = 10\,300 \pm 200^\circ$ K)
			$p = 0.98 \cdot 10$ [illegible]		
B, [illegible] $l = 1$ cm	$1{,}2 \cdot 10^3$	$0{,}75 \cdot 10^3$	$0{,}3 \cdot 10^3$	$2{,}1 \cdot 10^3$	$2{,}3 \cdot 10^3$
ε	$0{,}66 \cdot 10^{-3}$	$0{,}4 \cdot 10^{-3}$	$0{,}3 \cdot 10^{-3}$	$1{,}2 \cdot 10^{-3}$	$1{,}1 \cdot 10^{-3}$

their luminous abilities. A small range of change in the plasma temperature undoubtedly limits the perspective of utilizing the proposed variants in the process of investigating gases at high temperatures.

Measurement of temperature and luminous abilities of plasma from arc discharge in air N_2 and CO_2. The question concerning temperature measurements of plasma is inseparably tied with the question concerning the degree of its equilibrium. In Chapter [3] it was shown that at atmospheric pressure, the plasma in the column arc discharge in air and nitrogen, is in the condition of thermodynamic equilibrium, when for the computation of the plasma elements an intensity of radiating spectral lines, it is possible to use Sakh's and Baltsamann's formulas. Since present facts concerning the discharge of CO_2 into the atmosphere were lacking, special experiments were conducted on controlling the availability of equilibrium in plasma. Along with this, the method proposed in Chapter [3] was utilized, concerning instantaneous current cutoff, allowing for the determination of the difference between temperature, excitation and gas. Further investigation by the authors of these efforts showed, that the absence of intervals in the intensity of the spectral lines during quick cutting off of the discharge current also testified of the presence of decreasing equilibrium.

Observation in the drop of luminence was conducted along the line of coal Clλ = 247.8 nm, which was separated with the help of double quartz monochromator DMR-4. A photoamplifier R-3 with a cathode repeater was used to receive the luminence. Being constant upon entrance, it did not exceed 0.5 microseconds.

Investigation of the oscillographs showing the drop in the lumenence line Cl after instantaneous current cutoff, showed, that the time for full drop in luminence was 25-30 microseconds. During the full time luminence drops monotonously. The apparent clearly expressed skip in intensity, characteristic for a non-equilibrium case, was not determined.

Similar measurements were also conducted on continuous lumenence and on strips of C_2, well represented in the arc spectrum. In these cases, as in earlier ones, after current cutoff, the intensity falls monotonously, and the characteristic skips in intensity are lacking for nonequilibrium conditions. On the basis of these experiments, it is possible to conclude, that CO_2 plasma is close to equilibrium and that the different temperatures within the plasma do not exceed 100-200°K.

The arc plasma temperature is determined according to the absolute intensity of the lumination line with a known probability of transference. In case of discharge in air and CO_2, measurement of temperature was conducted along the oxygen line OIλ = 615.8 nm, and NIλ = 664.4 nm in air plasma conditions when the correspondence of concentrations of nitrogen atoms and oxygen atoms is known. The computed and experimental values of probability are equal correspondingly to 5.10^6 and 8.10^6 minus one second.

The probability of transition for which was found as the mean from the data of works [4-6] and was $7 \cdot 3 \cdot 10^6$ sec^{-1}. For measurements in nitrogen, we used the line NIλ = 664.4 mm. The probability of transition of this line was calculated by Gruzdev and measured by us by the intensity ratio of the lines OIλ = 615-8 mm.

Comparison of the intensity of the lumination of these lines under different thicknesses of the luminating layer (photograph of the length and perpendicular axis of the canal) showed, that a thickness of 2 cm reabsorption of their luminence may be considered negligible.

In the capacity of a source for comparison, a standard band heating lamp GOI No. 51 with a known temperature brightness was used. A comparison in the intensity of luminence between the line and the lamp was conducted by the general method of photographic photomeasurement.

The concentration of atoms of oxygen and nitrogen was located by the tables of thermodynamic functions of air [7] and thermodynamic qualities of individual substances [8].

Along with this, it is necessary to note, that for the regimes being investigated by us (T is approximately 9,000°K). Several deviations in temperature only slightly effect the atomic composition of the plasma and correspondingly have a small effect on the determined concentrations.

Because of the instability of the position of the canal, the air in the measurement of temperature discharged in the atmosphere and CO_2 is equal to 8%. For discharge in nitrogen and air, it does not exceed 3%. Experimentally measured values of plasma temperature actually have a smaller dispersion upon reproduction, then it follows from conducted evaluations of measurement error.

For discharge in air along the contour of the spectral line of hydrogen H_3, a determination of temperature lowering was conducted. The value of temperature derived in this manner is also presented in the table and in the limits of error in measurement, correspond with the value, measured according to the absolute intensity line of oxygen.

Determination of the luminence ability of air, N_2 and CO_2 was conducted in the spectral area of 200-3,000 nm, which was determined by the passage of air in quartz optics. In the capacity of a recuiver for luminence, a vacuum thermocouple LEGI with a quartz window was used, the spectral sensitivities of which is constant in the investigated integral of wave lengths. Registration of the thermal current was accomplished with the help of a photoelectric optical amplifier FEOU-15. Since the time constant of the thermocouple was a lot greater than the longevity of the impulse being measured, the experiment was conducted by using the ballistic method.

The sensitivity of the registering part of the thermocouple FEOU-15 was calibrated by the luminence of the luminence of the standard band lamp. Along with this a filter KS-11 was used to separate a known area spectrum from the luminence of the lamp, for which the energy radiated by the lamp was computed. For control in changes of sensitivity, devices of measurement with the lamp were conducted before and after measurements of arc luminence.

With the help of the diaphragm, situated immediately before the thermocouple, a preaxial high temperature zone was separated from the image of the canal, conducted for which were measurements of the temperatures of the arc plasma. In order to increase the accuracy of measurements, visual observation was conducted over the position of the canal relative to the diaphgram and results were noted. Besides this, out of the great amount of facts attained by this method, the most important facts were chosen.

Experimental values of the integral luminence ability of A air, N_2 and CO_2 according to the spectrum, are presented in the table. Here values are given to the degree of blackness and for the semi-spherical emitter with the radius of 1 cm, equal to the relationship of the measured energy from luminence with the energy of luminence of an absolute black body at plasma temperature in the investigated area of the spectrum 200-3,000 nm. Error in measurement of A for air and N_2, does not exceed 20%, for CO_2 - 40%. A comparatively low accuracy in measuring energy of luminence is stipulated in the basic indeterminibility of the arc. Let us note, that the instability of the position of the arc of the canal decreases the value of the measured energy of luminence canal, resulting in that the figures presented in the table show a lower limit of plasma luminence at assigned temperature and pressure.

For discharge in air, an evaluation of the inclusion of luminence of separate spectral areas into the integral plasma luminence was carried cut. Measurement showed, that for the regimes being investigated, approximately 60-70% of the plasma luminated energy comes into the area of the spectrum 60-3,000 nm.

It is necessary to note, that unfortunately, we did not have the chance to conduct a full comparison of results with the printed facts on hand [9-11], since the conditions of real measurement either on temperature or durability of plasma, were of the spectral interval under investigation, did not fully correspond to the conditions of measurement and computation of the literature cited. On the basis of approximate evaluations, it is possible to say, that the values derived by us for A and ε are in satisfactory correspondence with the facts presented by other authors.

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13. ABSTRACT

In an arc, stabilized by whirl currents of the gas being investigated, plasma is sucked through electrodes and in this way the progression of substance electrons into the canal is eliminated. There is an arc source, receiving a homogenous solumn of clear gas plasma. In the spectrum area of 0.2-3 mk, the integral luminosity of air, N_2 and CO_2 is measured. Measurement is accomplished at atmospheric pressure and at a temperature of approximately 10,000°K. Discharge in air is evaluated by the inclusion of the luminosity of several spectral areas into the integral luminosity of plasma.

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